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(54) **Thermally-insulating conduit**

(57) A thermally-insulating conduit comprising a supporting skin preferably polymeric, and a protective lining therefor of an insulating layer mineral such as vermiculite. The lining is preferably in the form of a compressed porous matrix of essentially closed cell beads with interstitial porosity and the conduits are particularly suitable for use in exhaust systems for internal combustion engines.

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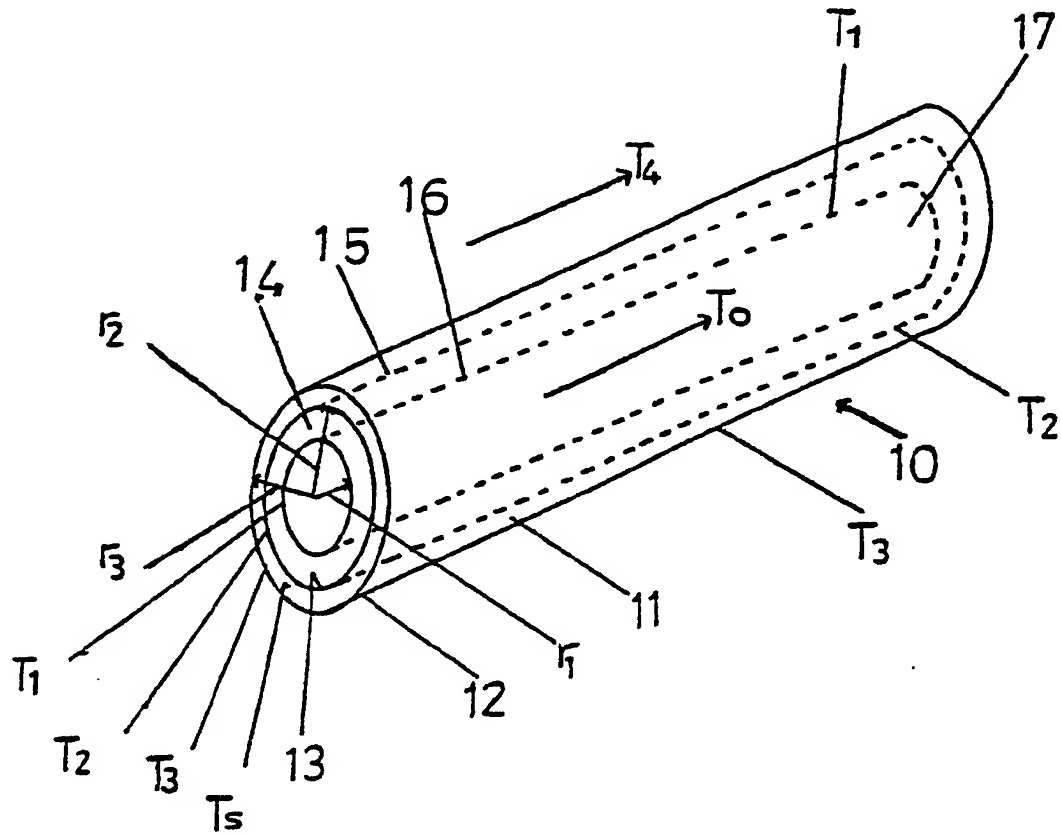

FIG 1

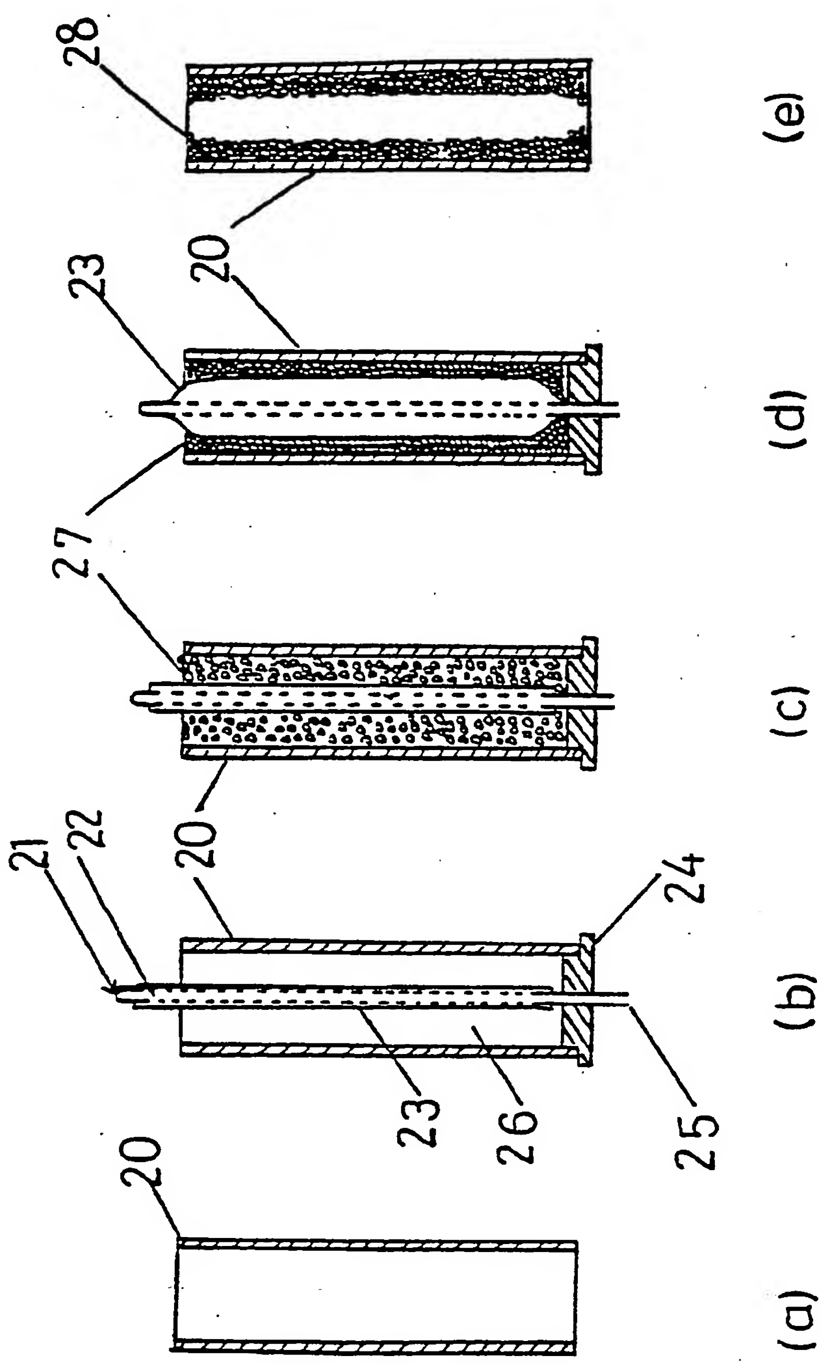

FIG 2

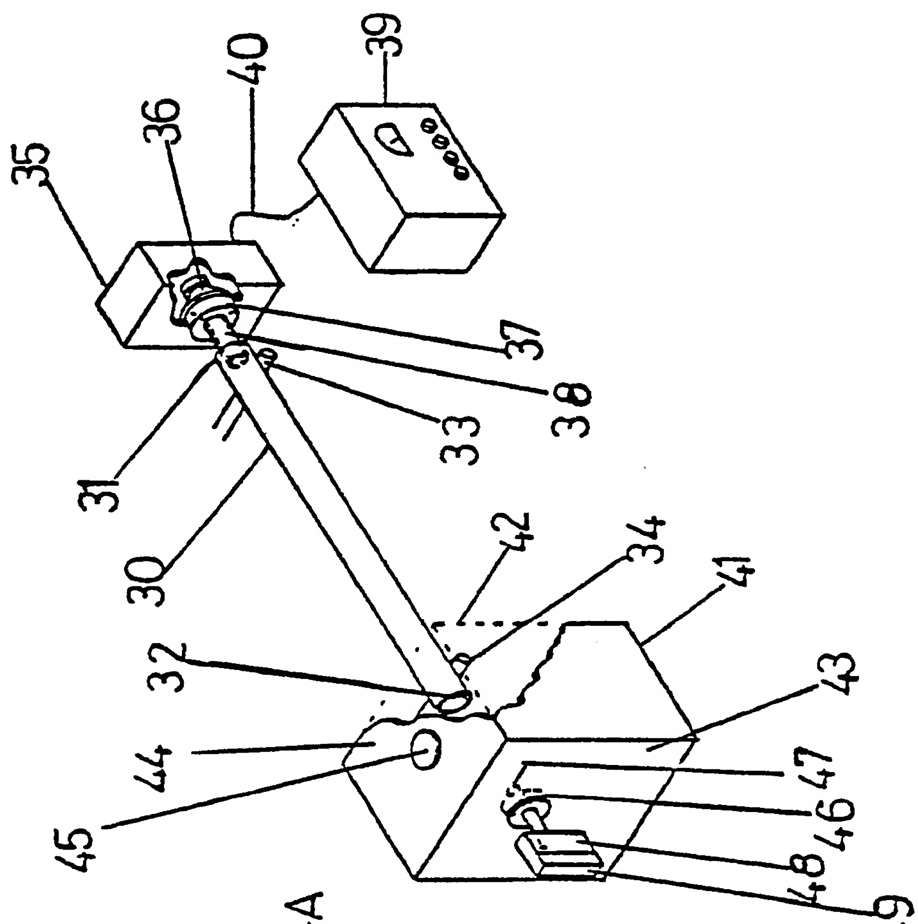
35
36
40
39
37
38
33
31
30
42
34
41
32
43
44
47
46
45
48
49

FIG 3

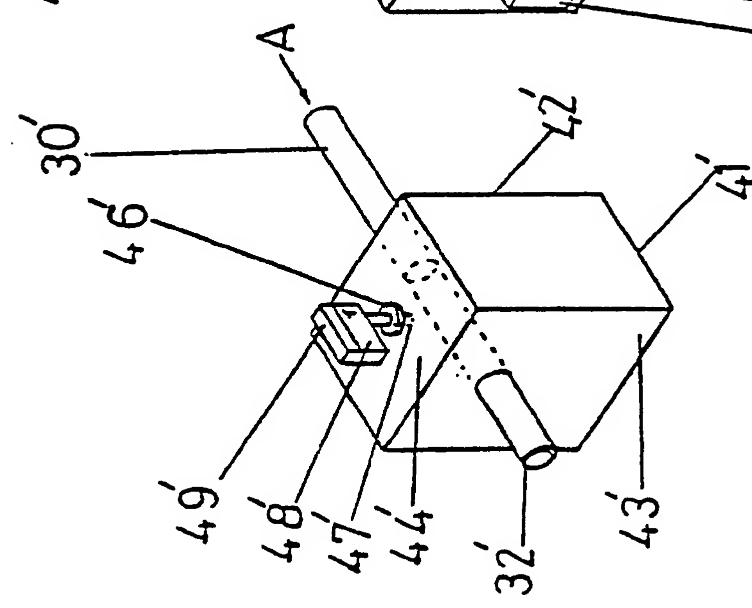
A
30'
42'
46'
41'
49'
48'
47'
44'
32'
43'

FIG 4

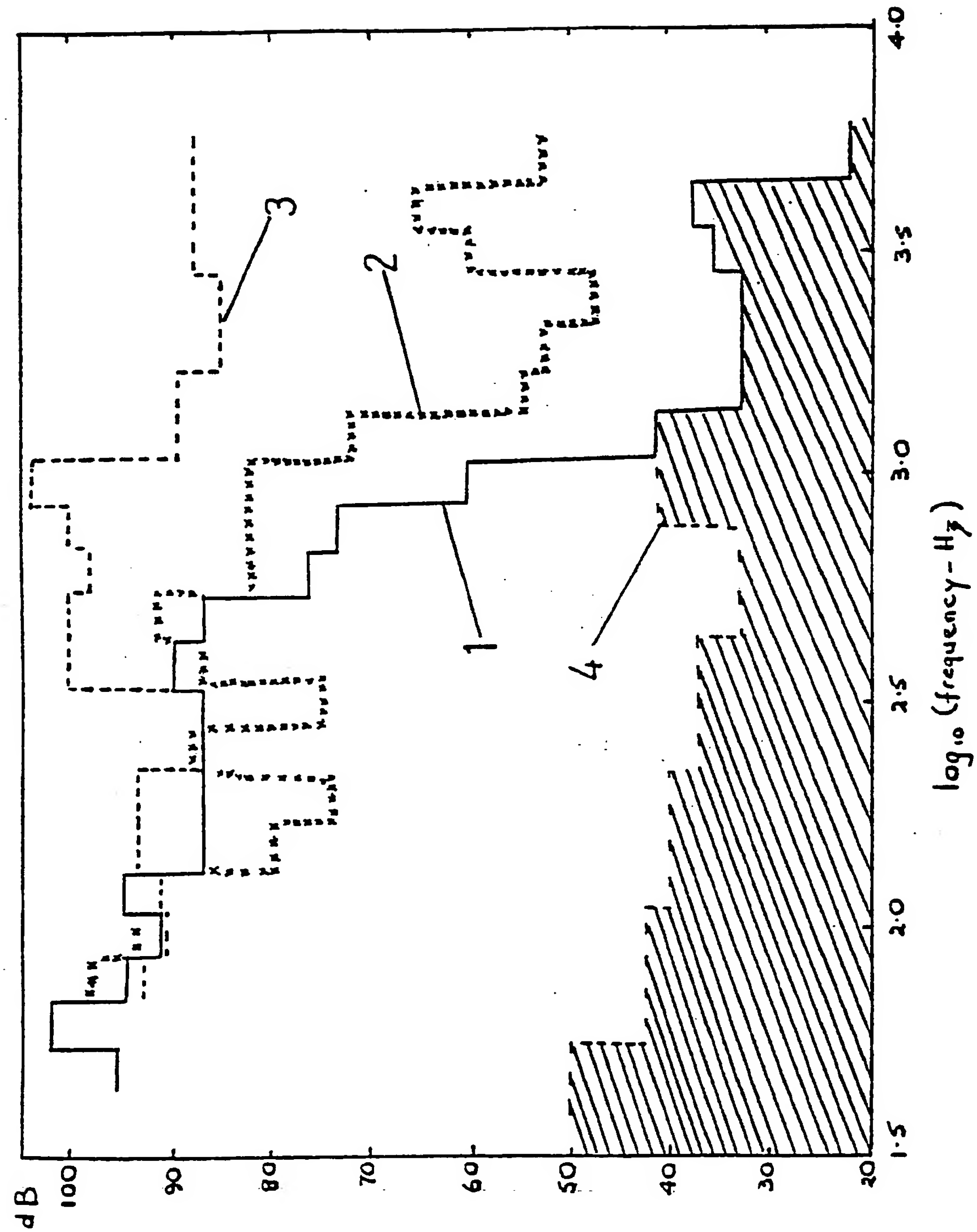
dB
100
90
80
70
60
50
40
30
20
1·5
2·0
2·5
3·0
3·5
4·0
1
2
3
4
log₁₀ (frequency - Hz)

FIG 5

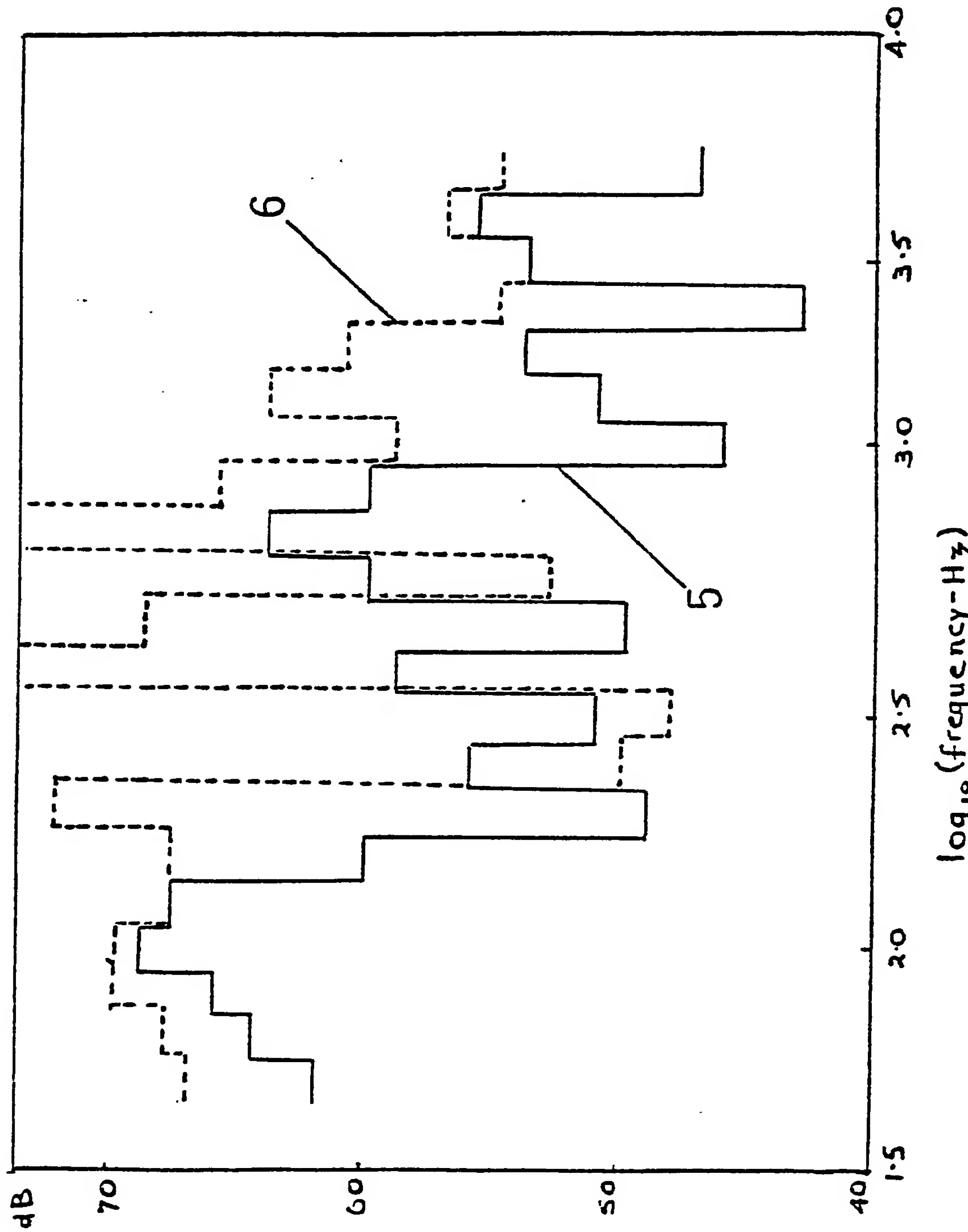

FIG 6

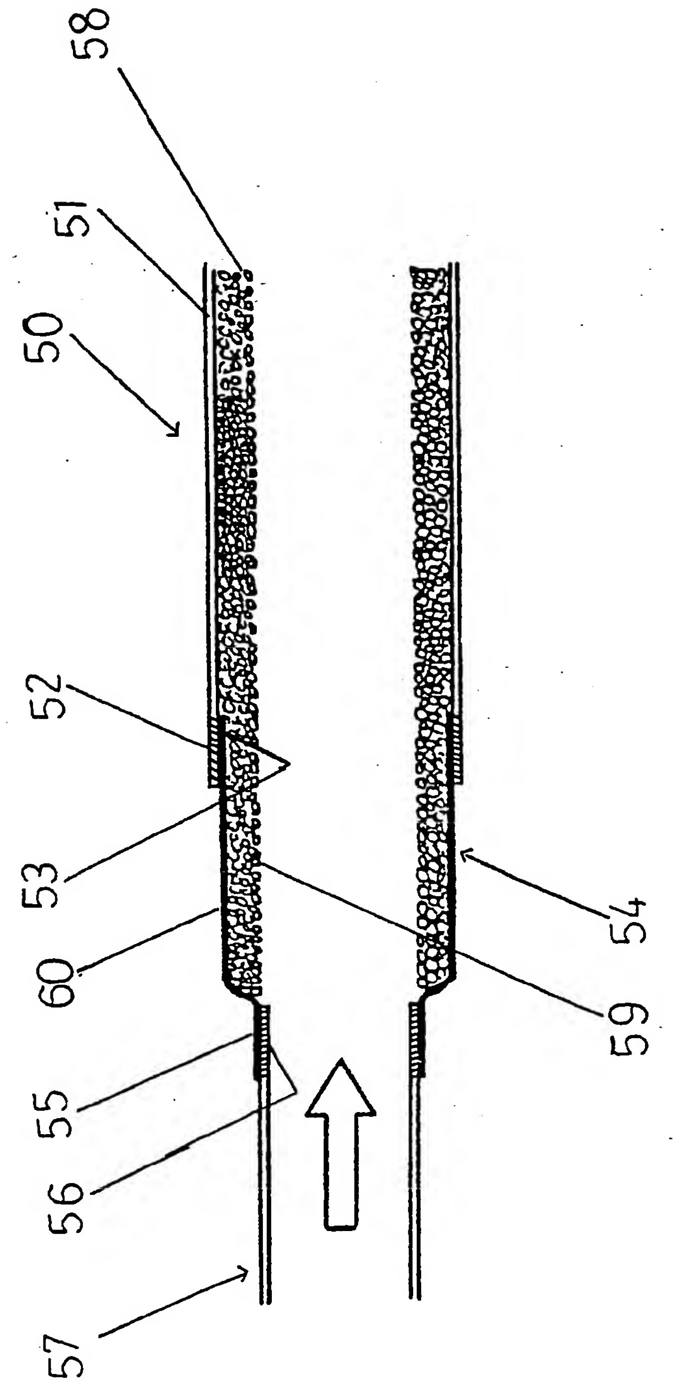

FIG 7

SPECIFICATION
Thermally-insulating conduit

This invention relates to a thermally-insulating conduit and, in particular, to a conduit suitable for exposure to hot gases.

Thermally-insulating conduits are of utility in a wide variety of applications and occur, for example, as components of ventilation ducts, flue liners and exhaust systems for internal combustion engines. Such conduits are frequently constructed from metals, such as mild or stainless steel, and are costly, heavy, difficult to fabricate into complex shapes and subject to corrosive degradation.

We have now devised an improved thermally-insulating conduit.

Accordingly, the present invention provides a thermally-insulating tubular conduit comprising a supporting skin having on at least the internal surface thereof a protective layer of a layer mineral.

In a preferred embodiment of the invention, the supporting skin comprises an organic polymeric material, and for convenience the invention is hereinafter described in terms of a conduit having such a polymeric skin.

Desirably, the protective layer is such that on subjecting the conduit to a temperature environment in which the protected surface is exposed to an elevated temperature of T_0°C the temperature thereby generated within the polymeric supporting skin, T_s°C, does not exceed $(T_0\text{-}A.B)$°C, wherein A is a function of the temperature environment and of the emissivity of the polymeric material as hereinafter defined, and B is a function of the geometry and thermal conductivity of the insulating layer as hereinafter defined and is within a range of from 0.5 to 50.

Although a conduit according to the invention may be of any desired configuration, it is convenient to consider a conduit.of cylindrical tubular form, which is particularly suitable for incorporation into fluid-flow systems, such as an exhaust conduit for an internal combustion engine. Therefore, the invention is hereinafter described in terms of a conduit of cylindrical form, although it will be appreciated that alternative configurations are envisaged.

From a consideration of a conduit in the form of a cylindrical tubular skin of polymeric material lined with an annular protective layer of an insulating material and positioned in a surrounding fluid medium at a temperature of T_4°C, a fluid medium at a temperature of T_0°C (greater than T_4) flowing through the interior of the protective lining, it can be shown that the heat loss per 2 unit lengths of the conduit is:

$$A = \frac{T_o - T_1}{1/h_1r_1} = \frac{T_3 - T_4}{1/h_3r_3} + \frac{(T_3{}^4 - T_4{}^4)}{1/\,\sigma r_3},$$

where

T_1 is the temperature at the internal surface of the lining,

T_3 is the temperature at the external surface of the polymeric skin,

h_1 is the convection heat transfer coefficient between the internal medium and the lining,

h_3 is the convection heat transfer coefficient between the polymeric skin and surrounding medium,

r_1 is the internal radius of the lining,

r_3 is the external radius of the polymeric skin,

is the emissivity of the polymeric skin, and

σ is the radiation proportionality constant.

Similarly, it can be shown that suitable insulating lining materials exhibit a parameter B within a range of from 0.5 to 50, wherein

$$B = \frac{1}{h_1r_1} + \frac{\ln(r_2/r_1)}{k_1}$$

where

h_1 and r_1 are as hereinbefore defined,

r_2 is the external radius of the lining, and

k_1 is the thermal conductivity of the lining material.

Consequently, selection of polymeric skin and internal lining materials of appropriate composition, structure, thickness and thermal conduction and emission characteristics provides a conduit in which the maximum temperature developed in the skin, T_s°C, may be maintained at a level which is compatible with the thermo-mechanical constraints of the skin and lining components and in particular at a level not exceeding $(T_0\text{-}A.B)$°C, wherein A and B are as hereinbefore defined.

The skin may be fabricated from any suitable supporting material of adequate stiffness to prevent or minimise strain-induced damage of the protective layer when in use. The skin may be of a metallic, inorganic, or organic polymeric material, or a composite structure thereof. Desirable skin-forming materials include thermosetting or thermoplastics resins capable of withstanding the specified maximum skin temperature, T_s, thermoplastics materials being particularly suitable because of their ease of fabrication. Desirably, the melting temperature of the polymeric material should exceed the anticipated T_s by at least 20°C, and thermoplastic polymers with desirably high melting temperatures include polyolefins, such as polypropylene (170°C), polyesters, such as polyethylene terephthalate (260°C) and polyamides, such as polyhexamethylene adipamide (250°C). Preferably, the selected polymer exhibits a density of at least 90 kg m^{-3}, a flexural modulus (ASTM D790-71) of at least 1.0 GPa and a tensile yield strength (ASTM D638-77a) of at least 30 MPa.

If desired, the polymeric skin may be strengthened by the presence therein of a reinforcing agent, such as glass fibres. Desirably, the content of reinforcing agent is within a range of from 5 to 60% by weight of the skin.

Fabrication of the skin is effected by known

forming techniques including casting, extrusion, pultrusion or filament- or tape-winding. Conveniently, a skin is preformed and subsequently provided with a protective lining of insulating material, but, if desired, the skin may be applied to a preformed liner. In effect the skin serves as a support for the insulating liner and may be relatively thin — for example, of the order of 0.2 mm or greater.

The insulating material forming a protective layer on at least the internal surface of the tubular skin comprises a layer mineral, such as a phyllosilicate mineral, i.e. a mineral having a layer structure capable of chemical and mechanical delamination or defoliation to yield thin lamellae or flakes having a high aspect ratio (i.e. length or breadth divided by thickness).

A preferred phyllosilicate mineral is vermiculite, including all materials known commercially and mineralogically as vermiculite — such as chlorite-vermiculites which contain a substantial proportion of vermiculite layers susceptible to defoliation. Suitable minerals also include montmorillonite, kaolinite (and clays comprising kaolinite, such as kaolins and ball clays) and other layer-silicate minerals which can be delaminated to lamellae or platelet-like particles, or mixtures of one or more thereof with a proportion of vermiculite.

Typical platelets obtained by chemical defoliation of vermiculite have a thickness of less than 0.5 micron (μm), usually less than 0.05 μm and frequently less than 0.005 μm, with an aspect ratio of at least 100 and preferably at least 1000.

The protective insulating material may be applied to the skin from a suspension in a suitable carrier medium, such as an organic liquid or an aqueous medium, the viscosity characteristics of the suspension being selected for ease of handling in the desired application and to facilitate the deposition of an insulating layer of the desired thickness. Typically, the solids content will be from 2 to 50%, preferably from 10 to 25%, by weight of the suspension, and, after deposition of the insulating material, the surplus carrier medium may be removed by draining and/or evaporation. Conveniently, a phyllosilicate mineral insulating material may be deposited on the skin directly from the suspension resulting from the process employed to effect chemical defoliation of the mineral, a typical vermiculite suspension being disclosed in British patent 1 582 121.

If desired, the insulating material may be deposited on the skin in the form of a cellular matrix. In the case of a phyllosilicate mineral, such as vermiculite, a suspension of the mineral in a liquid medium may be gasified to produce a froth which on removal of the liquid medium by evaporation yields a rigid mineral foam cellular matrix. Conversion of a suspension of vermiculite lamellae to a rigid cellular matrix of this kind is disclosed in British patent 1 585 104. Deposition of the gasified froth onto the polymeric skin and subsequent drying to eliminate the liquid medium leaves on the skin a rigid, thermally-insulating cellular foam matrix of light weight, the density of such foams generally being less than 500 kg m^{-3} and usually less than 150 kg m^{-3}. Variation of the foam density to a desired level may be achieved by varying the volume of gas employed in the gasification technique or by altering the solids content of the suspension.

In a preferred embodiment of the invention of particular utility in the production of exhaust conduits for internal combustion engines, the protective layer of insulating material is in the form of a porous cellular matrix comprising discrete beads or particles of essentially closed-cell structure. Effectively, therefore, the protective layer is a matrix comprising beads of essentially closed cell structure assembled to provide a degree of interstitial porosity between beads. Desirably, a mass of individual beads (dry or moist) each with an essentially closed-cell structure is compacted (under low pressure) to form a porous agglomerate with a substantial degree of voiding between adjacent beads. The degree of voiding is conveniently in a range of from about 5 to 60% by volume of the matrix and may be varied as appropriate to achieve a desired blend of thermal resistance, density and acoustic characteristics (as hereinafter described). The individual cellular beads may comprise a phyllosilicate mineral such as vermiculite.

The protective function of the insulating material depends, inter alia, on the thickness thereof and in general it is preferred that the thickness of the insulating layer should be at least 0.5 mm.

Although lamellae of vermiculite and some other phyllosilicate minerals exhibit self-adhesive characteristics, it may be desirable, particularly in the case of the aforementioned cellular bead structure, to incorporate into the insulating material a binder to improve the strength and durability thereof. Suitable binders include phosphates and silicates — such as sodium silicate. Other additives may, if desired, be included in the insulating protective layer to improve or modify the physical or chemical characteristics thereof — for example, to improve thermal resistance, flexibility, abrasion resistance or moisture-stability.

Although as hereinbefore described the insulating material may be deposited on the polymeric skin from suspension in a suitable carrier medium, in a preferred embodiment of the invention the insulating material is applied to the skin by a compressive moulding technique, whereby the insulating material in granular or powder form (and preferably in the absence of a carrier medium) is placed in contact with a surface of the skin and compressed into intimate contact therewith by the application of a relatively low and substantially uniform pressure.

A particularly useful compressive moulding technique for producing conduits according to the invention is a modification of an isostatic technique hitherto employed in the production of preforms of polytetrafluoroethylene. The isostatic moulding technique depends on the use of a

member the end portions of which are respectively dimensioned for gas-tight engagement with the supporting skin of a conduit and with a pipe, the tubular member being of a thermally-resistant material and having on the internal surface thereof a protective layer of a thermally-insulating material.

The member is conveniently fabricated from a metal, such as mild steel, which provides an acceptable degree of thermal resistance. Any suitable material may be employed to provide the required degree of internal thermal insulation but a layer mineral is preferred, particularly the same layer mineral as that employed to line the conduit of the invention. Desirably the layer mineral is of the same form, as that within the conduit e.g. in the form of a porous matrix of an essentially closed cell structure.

The end portions of the tubular coupling member may be dimensioned to fit either internally or externally of the conduit or pipe, although for attachment to a conduit the coupling dimension is preferably such that the external surface of the coupling affects a close sliding fit within the internal surface of the conduit skin. Mechanical constraint against displacement of the coupling may then be simply provided — for example, by a jubilee clip encircling an end portion of the conduit skin. Other forms of mechanical constraint may be employed, if desired, for example — crimping of the coupling member onto the conduit and/or pipe, and, optionally, a sealing and/or adhesive composition may be introduced between the cooperating end surface portions of the coupling and the conduit and/or pipe.

The coupling member assists cooling of the hot gases entering the conduit and, desirably, should be provided with a matt (black) external surface to increase thermal emissivity. The length of the coupling may be selected to provide the required degree of cooling commensurate, inter alia, with the thermal resistance of the conduit skin material and the temperature of the gases being delivered from a pipe for introduction into the conduit. The desired coupling length may be established by experimentation or calculation. By way of example, it has been established that for a simple tubular coupling of internal diameter 40 mm, fabricated from metal of 1 mm thickness and lined with a layer of vermiculite foam of 10 mm thickness, to which are introduced exhaust gases at a temperature of at least 400°C, the surface temperature of the coupling will decrease to less than 150°C within a coupling length of less than 100 mm. If desired, the coupling may comprise means to assist dissipation of heat therefrom — for example, surface fins, or a bellows structure which increases surface area and, additionally, introduces a desirable element of flexibility into the assembly.

In a preferred embodiment of the invention, the end portion of a coupling member is introduced into the cooperating end portion of a conduit skin, and a layer mineral insulating material is thereafter applied to the inner surfaces of the coupling and of the skin by an isostatic moulding technique as hereinafter described with reference to Figure 2 of the drawings.

The invention is illustrated by reference to the accompany drawings in which:

Figure 1 is a schematic perspective view of a tubular thermally-insulating conduit,

Figures 2a to 2e inclusive are schematic sectional elevations of stages in the production of a tubular conduit by an isostatic moulding technique,

Figure 3 is a schematic perspective view of an acoustic test assembly for transmitted sound,

Figure 4 illustrates the acoustic test assembly in use to assess radiated sound,

Figure 5 depicts the acoustic behaviour of a tubular conduit tested on the assembly of Figure 3 for transmitted sound,

Figure 6 similarly depicts the acoustic behaviour of a tubular conduit for radially radiated sound assessed on the assembly of Figure 4, and

Figure 7 is a schematic sectional elevation of a conduit segment and associated coupling member.

Referring to Figure 1 of the drawings a tubular conduit, generally designated 10, comprises a cylindrical polymeric skin 11, suitably of polyethylene terephthalate reinforced with glass fibres, having an outer surface 12 of external radius r_3, and an inner surface 13 of internal radius r_2. An annular insulating lining 14, suitably of a phyllosilicate mineral such as vermiculite, having an outer surface 15 of radius r_2 and an inner surface 16 of internal radius r_1 is fitted within skin 11, inner surface 13 of the skin and outer surface 15 of the lining being in close contact.

For the purpose of assessing the skin temperature T_s°C, as hereinbefore described, the conduit may be regarded as located within a surrounding atmosphere of a fluid at a temperature T_4°C. On passage through the lumen 17 of the tubular conduit of a fluid at a temperature of T_0°C, temperatures of T_1, T_2 and T_3°C are generated at the respective internal and external surfaces of the lining and skin, and a temperature of T_s°C within the skin.

Referring to Figures 2a to 2e of the drawings a length of extruded polymeric tubular skin 20 is depicted in Figure 2a. In Figure 2b a deformable applicator 21 comprising a relatively rigid tubular perforated mandrel 22 enclosed within a flexible deformable tubular sheath 23 is introduced into skin 20 and releasably secured therein by removable plug 24, the hollow mandrel being connected to a low pressure gas source (not shown) by supply line 25.

In Figure 2c the annular space 26 between the applicator 21 and skin 20 has been loosely filled under gravity by a charge of particulate material such as vermiculite particles 27.

In Figure 2d the low pressure gas supply has been switched on thereby inflating sheath 23 to compress particulate charge 27 against the internal wall of skin 20, and in Figure 2e the sheath has been deflated and the mandrel

deformable applicator whereby (fluid) pressure may be applied uniformly to all parts of a mouldable particulate material confined within a removable, metal, mould shell thereby ensuring that the resultant moulding is substantially homogeneous. In the case of polymeric mouldings thus produced from granular polytetrafluoroethylene under relatively high pressures, the isostatically compressed moulding, after removal of the mould shell, is sintered to yield a coherent product. In an embodiment of the present invention the preformed polymeric skin serves as a non-removable mould shell, and the particulate insulating material is isostatically compressed thereon, thereby being bonded thereto.

The isostatic moulding technique is applicable to the production of moulded articles of diverse shapes, particularly tubular conduits having an internal protective lining — for example, by a technique similar to that disclosed in British patent 799 544. The pressure applicator may be a flexible membrane deformable under the influence of fluid pressure as disclosed in the immediately aforementioned British patent, or a resilient body radially deformable under the influence of an axially applied mechanical ram pressure as disclosed in British patent 881 701.

Production of conduits according to the invention by the isostatic compression technique requires the application of only relatively low pressures — for example within a range of from about 0.05 to 1.0 MN m^{-2}, but if higher pressures exceeding the rupture stress of the polymeric skin are required the skin may be temporarily supported during the moulding operation by a suitably supportive backing member or shell.

Post-forming of the applied lining material may be effected, if desired, to modify the shape or characteristics of the internal surface thereof.

Although the protective lining enables a conduit with a polymeric skin to resist relatively high temperatures it may be desirable in some cases to provide means to assist dissipation of heat from the polymeric skin. For example, in the case of an exhaust assembly for a motor vehicle internal combustion engine where the exhaust assembly will be exposed, during movement of the vehicle, to an external current of air at a relatively low temperature, it may be desirable to provide, on at least part of the external surface of the exhaust assembly, a fin assembly whereby the effective external cooling surface of the exhaust assembly is increased.

An exhaust assembly for an internal combustion engine of the kind employed in motor vehicles usually comprises a pair of chambers inter-connected and linked to the engine manifold by an appropriate conduit, the first proximal chamber nearer the engine usually acting as a simple expansion chamber which absorbs the low frequency (e.g. less than 500 hertz, Hz) sound vibrations in the exhaust gases emerging from the manifold, while the second distal chamber further from the engine acts as a fluid-frictional device to remove higher frequency (>500 Hz) sound vibrations. The distal chamber usually comprises a chamber of circular or elliptical cross-section having an inlet at one end and an outlet at the other end linked within the chamber by a continuous apertured conduit surrounded by an absorbent packing of rock wool or glass fibre. Typical exhaust gas temperatures encountered respectively in the proximal and distal chambers are of the order of 550 and 300°C for a petrol engine, and 250 and 150°C for a diesel engine.

An exhaust conduit fabricated according to the invention, in addition to exhibiting desirable thermal stability has been observed to possess surprisingly beneficial sound absorption characteristics particularly at higher frequencies above 500 Hz. The hereinbefore described compressed porous matrix of essential closed cells is particularly effective in this respect due to interstitial porosity and is capable of effecting a significant reduction in both radiated and transmitted high frequency sound. An exhaust assembly comprising a single chamber fabricated according to the invention therefore effectively silences an internal combustion engine and eliminates the requirement for a multiple chamber assembly.

Uniform interstitial porosity need not be retained throughout the entire thickness of the protective layer to achieve adequate acoustic performance, but the porosity is desirably at a maximum level at the inner surface (minimum radius) of the layer. Should enhanced surface integrity of the protective layer be required, a porous liner may be provided within the bore of the conduit.

It has been observed that the back-pressure experienced by an engine silenced by an exhaust conduit according to the invention is less than that experienced with a conventional steel exhaust assembly, thereby providing a potential improvement in the efficiency of the engine.

In using a conduit according to the invention it will usually be necessary to couple one or both ends of the conduit to a pipe. For example, a conduit employed as a silencer for an internal combustion engine, particularly for a motor vehicle, may have to be connected to the hot gas discharge pipe leading from the exhaust manifold of the engine. The conduit comprises a supporting skin, generally of a material which is susceptible to damage at high temperatures, insulated from the hot gases by a protective mineral layer which, in general, does not exhibit great mechanical strength. Coupling of a conduit to a pipe should therefore be effected with care to avoid disruption of the mineral layer and the potential introduction into the assembly of an inherent mechanical defect which may eventually lead to failure — for example, if the assembly is exposed to excessive vibration or subjected to rough treatment. Desirably, therefore, the conduit is associated with a simple mechanical coupling for attachment to a pipe.

A suitable coupling comprises a tubular

assembly withdrawn to leave a thermally insulating conduit comprising a polymeric skin 20 having on the internal surface thereof a compressed porous cellular matrix 28.

Referring to Figure 3 of the drawings a tubular conduit 30 having an inlet end 31 and an outlet end 32 is mounted for acoustic testing on a simple support 33, 34 adjacent each end of the conduit.

A speaker cabinet 35, approximately 130 × 190 × 320 mm, lined with sound absorbent cork, and containing a loud speaker 36 of approximately 75 mm diameter, is fitted with a brass horn 37 the stem 38 of which is introduced into the inlet end 31 of the conduit and acoustically sealed thereto by a draped cloth or similar packing (not shown).

A frequency generator 39, suitably type SG66 supplied by Advance Electronics Ltd, is coupled to loud speaker 36 by a suitable lead 40.

A closed receiving chamber 41 located adjacent the outlet end of the tubular conduit has a rectangular front wall 42 and rear wall 43 (approximately 540 × 460 mm), a square top wall 44 (approximately 460 × 460 mm) and is lined with an acoustic damping layer (not shown) of cork (approximately 12 mm thick). An aperture in the top wall is closed by a removable rubber plug 45. A rubber collar 46 centrally located in rear wall 43 supports a microphone 47, suitably a B & K calibrated model IE2P, coupled to a real time spectrum analyser 48, suitably type IE30A supplied by Ivie Electronics Inc, with an audio analyser 49, suitably type IE17A supplied by Ivie Electronics Inc.

In operation of the acoustic test assembly, the outlet end 32 of the tubular conduit is introduced into receiving chamber 41 through front wall 42 thereof and acoustically sealed therein so that outlet end 32 stands proud of the internal layer of cork at a position directly opposite microphone 47 located in rear wall 43. Sound of selected frequency generated by generator 39, amplified by speaker 36 and transmitted axially along the interior of conduit 30 is gathered by microphone 47 and analysed by analyser 49.

In the modification shown in Figure 4 to assess radially radiated sound, the sound generating and amplifying equipment 39, 36, remains unchanged but rubber plug 45 in the top wall 44′ of receiving chamber 41′ is replaced by collar 46′ and its associated microphone 47′, spectrum analyser 48′ and audio analyser 49′. The tubular conduit 30′ under test enters front wall 42′ and extends continuously through receiving chamber 41′, so that the outlet end 32′ of the conduit projects outwardly of rear wall 43′, the conduit being acoustically sealed into walls 42′ and 43′. Sound generated as described in relation to Figure 3 enters the conduit in an axial direction as shown by arrow A, and a proportion thereof diffuses radially through the lining and skin of conduit 30′ to be gathered by microphone 47′ and analysed by analyser 49′.

Figure 5 records the frequency pattern of axially transmitted sound assessed by the technique described in relation to Figure 3. Curve 1 records the behaviour of a tubular conduit according to the invention comprising a tubular skin of glass-filled polyethylene terephthalate having a length of 1.8 metres, internal diameter of 63 mm and wall thickness of 1 mm lined with a protective layer (10 mm thick) of compressed vermiculite beads of essentially closed cell structure. Curve 2 records the behaviour of a steel tube of similar bore and length fitted with a typical motor vehicle exhaust silencer of 10 cm diameter and length 23 cm, while curve 3 records the behaviour of an unlined plastics pipe of diameter 6 cm, length 90 cm and wall thickness 1 mm. The superior behaviour of the conduit of the invention, particularly in reducing the level of transmitted sound to the level of the background sound intensity (curve 4) at $\log_{10}$ (Hz) values greater than about 2.7 (frequency 500 Hz) is evident.

Figure 6 records the frequency pattern of radially radiated sound assessed by the technique described in relation to Figure 4. Curve 5 records the behaviour of the conduit described in relation to curve 1 of Figure 5, while curve 6 records the behaviour of an unsilenced steel pipe of 4 cm bore similar to that of curve 3 of Figure 5. The superior acoustic behaviour of the conduit according to the invention is again evident, particularly in relation to radiated sound at frequencies greater than about 500 Hz.

Referring to Figure 7 of the drawings, a segment 50 of a conduit comprises a polymeric skin 51 into an end portion 52 of which is introduced a closely-fitting end portion 53 of a mild steel tubular coupling member 54 the other end portion 55 of which is dimensioned to fit closely around the external surface of the end portion 56 of a discharge pipe 57 through which hot gases flow in the direction of the arrow from the exhaust manifold (not shown) of an internal combustion engine (not shown).

A gas-tight joint between the conduit and coupling member is effected by a jubilee clip (not shown) secured around end portion 52 sufficiently tightly to compress that end portion of the relatively flexible conduit skin into engagement with end portion 53 of the coupling member. A joint between coupling member 54 and pipe 57 may be effected in similar manner.

The compressed porous cellular vermiculite matrix 58 on the internal surface of conduit skin 51 is extended to form a protective layer 59 on the internal surface of the coupling member over an intermediate portion 60 extending between the respective end portions 53 and 55 thereof, the conduit and coupling member having been assembled together prior to formation of the internal protective layer by an isostatic moulding technique. It will be appreciated that the coupling member may be independently coated with an internal protective layer and supplied as a separate entity for connection to the conduit when required.

When tested under ambient conditions it was observed that with gases at a temperature of

about 400°C passing through the assembly a mild steel coupling member (1 mm thick; 40 mm internal diameter; vermiculite lining 10 mm thick) experienced a drop in external surface temperature (recorded by contact thermocouples) to less than 150° over an intermediate portion of less than 100 mm, the recorded surface temperatures depending inter alia, on the speed of the assembly through the ambient environment. For example, at a speed of about 70 mph the observed surface temperature at end portion 55 was 206°C and that at end portion 53 was 110°C. Comparable values with the assembly at rest were 129 and 101°C respectively.

CLAIMS

1. A thermally-insulating tubular conduit characterised by a supporting skin having on at least the internal surface thereof a protective layer of a layer mineral.

2. A conduit according to claim 1 characterised in that the protective layer is such that on subjecting the conduit to a temperature environment in which the protected surface is exposed to an elevated temperature of T_0°C the temperature thereby generated within the polymeric skin, T_s°C, does not exceed $(T_0 - A.B)$°C wherein A is a function of the temperature environment and of the emissivity of the polymeric material as hereinbefore defined, and B is a function of the geometry and thermal conductivity of the insulating layer as hereinbefore defined and is within a range of from 0.5 to 50.

3. A conduit according to either of claims 1 and 2 characterised in that the layer mineral comprises a phyllosilicate mineral.

4. A conduit according to claim 3 characterised in that the phyllosilicate mineral is vermiculite.

5. A conduit according to any one of the preceding claims characterised in that the protective layer comprises a porous matrix of beads of an essentially closed cell structure.

6. A conduit according to any one of the preceding claims characterised in that the skin comprises an organic polymeric material.

7. A conduit according to claim 6 characterised in that the organic polymeric material is a polyester.

8. An assembly comprising a conduit according to any one of the preceding claims and a coupling for connecting the conduit to a pipe characterised in that the coupling comprises a tubular member of a thermally-resistant material and on the internal surface thereof a protective layer of a thermally-insulating material.

9. An assembly according to claim 8 characterised in that the thermally-insulating material on the internal surface of the tubular member is a layer mineral.

10. An exhaust assembly comprising a conduit according to any one of claims 1 to 7 and, optionally, a coupling as defined in either of claims 8 and 9.

11. A method of producing a thermally-insulating conduit according to any one of claims 1 to 7 characterised by providing on at least the internal surface of a tubular supporting skin a protective layer of a layer mineral.

12. A method according to claim 11 characterised by assembling together a conduit supporting skin and a coupling member and applying a protective layer of a layer mineral to the respective internal surfaces of the skin and coupling member.

13. A method according to either of claims 11 and 12 characterised by forming the protective layer by an isostatic compressive moulding technique.

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